> party to celebrate the event by a reporter from the *Columbus Dispatch*. I must have been less than sharp in answering his questions. That renewal did make me realize that it would be appropriate to thank someone for this generous support of my graduate studies. The man who had proposed NSF and steered the bill through Congress was none other than the immediate past President, Harry S Truman, a man whom I admired even back in 1954. So a letter expressing my appreciation went off to him that summer. A letter in an expensive looking envelope with a Kansas City return address arrived in early October.

Lednicer made available a copy of that letter, whose tone is quintessentially Trumanesque:

> *October 2, 1954*
>
> *Dear Mr. Lednicer:*
>
> *Your good letter of September 21 was very much appreciated.*
>
> *I always knew that the Science Foundation would do a great amount of good for the country and for the world. It took a terrific fight and three years to get it through the Congress, and some smart fellows who thought they knew more than the President of the United States tried to fix it so it would not work.*
>
> *It is a great pleasure to hear that it is working and I know it will grow into one of our greatest educational foundations.*
>
> *Sincerely yours,*
>
> */s/ Harry S Truman*

One thing that is obvious is that the past 50 years' investments in research and education have been an excellent investment in people, ideas, and tools. It is hoped that the next 50 years will be equally as productive and exciting.

Enduring Themes: Continuity and Change

The 1948 and 1998 speeches delivered by Presidents Truman and Clinton, compared and contrasted in an earlier section, qualify as significant indicators of the science policy priorities of those respective presidents. But presidential addresses are rare and subject to time constraints. As a result, only the most essential of their priorities can be presented in public forums.

A comparison of other documents from the 1940s and the current time of transition reinforce a conclusion reached in comparing the speeches made by President Truman and by President Clinton 50 years later: namely, that whereas there is an enduring quality to the science policy themes articulated a half-century ago, changes have also occurred within those overarching themes. In some cases, issues associated with a particular theme have not changed a great deal. In other cases, the character of the issues are very different, reflecting the largely unpredictable changes that have occurred both as a result of advances in science and engineering, and in the social, political, and economic contexts in which science and engineering activities take place.

Examples of the enduring character of many science policy themes, along with changes in emphasis, can be discerned by comparing some of the principal themes presented in *Science—The Endless Frontier* and *Science and Public Policy* with those presented in *Science in the National Interest* and *Unlocking Our Future,* in addition to those discussed in greater detail in subsequent chapters of *Science and Engineering Indicators – 2000.*

Support and Performance of R&D

National R&D Expenditures

Science and Public Policy included data on estimated U.S. R&D expenditures for 1947 (Steelman 1947, vol. I, 12, table II). (See text table 1-3.) The approximately $1.2 billion expended during that year was a record high. Nevertheless, the report argued that a national research program that would be adequate to address the Nation's needs would require that those expenditures double by 1957 so that they would then constitute 1 percent of national income (that is, GDP).

Today, total national R&D expenditures for 1998 were estimated at $220.6 billion, or 2.61 percent of GDP.[50] (See chapter 2.)

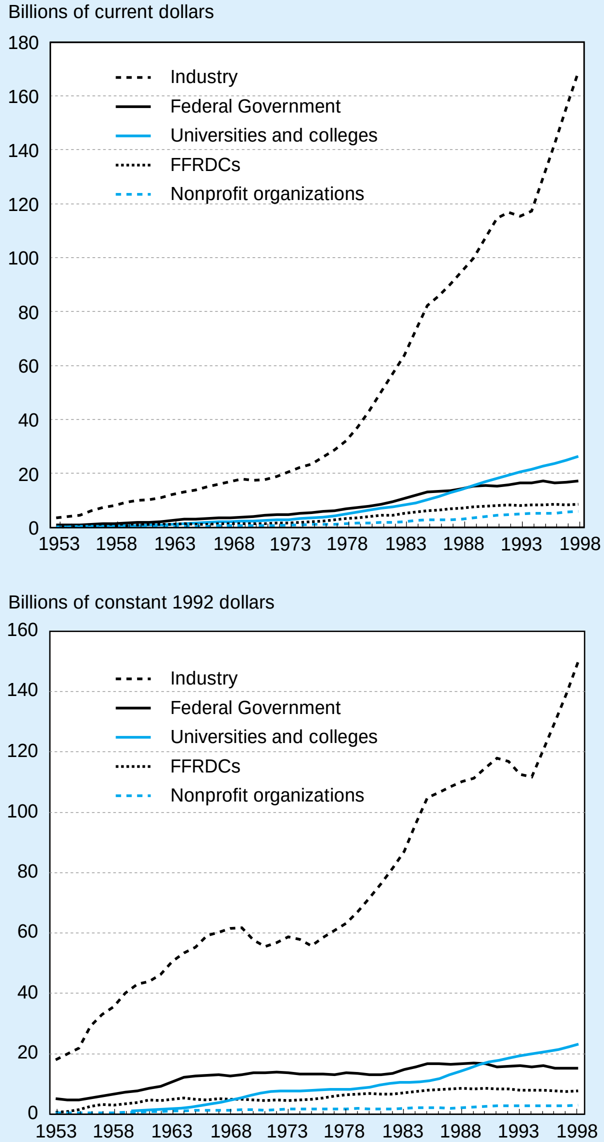
Sources of R&D Expenditures

Science—The Endless Frontier included pre-World War II data on sources of national R&D expenditures (Bush 1945a, 86), and *Science and Public Policy* included similar data for 1947 (Steelman 1947, vol. I, 12). According to the former, industry accounted for almost 68 percent of total national R&D expenditures in 1940, with the Federal Government accounting for about 19 percent, universities for 9 percent, and other sources for about 4 percent. (See text table 1-3 and figure 1-2.) During World War II, the Federal Government became the dominant supporter of R&D, a condition that continued during the early postwar years. In 1947, according to the Steelman report, the Federal Government accounted for approximately 54 percent of national R&D investments and industry for about 40 percent, with universities and other sources each contributing less than 4 percent. (See text table 1-3.)

After the end of World War II in 1945, industrial R&D investments increased, while Federal expenditures declined so that by the end of the decade industry was once again the leading supporter of R&D in the country. The Korean War, which began on June 25, 1950, a few days before the start of FY 1951, led to a rapid increase in defense R&D expenditures so that, beginning in 1951, Federal contributions exceeded those of industry. That situation continued until 1980, when industrial R&D investments equaled and then began to exceed those of the Federal Government. (See text table 1-3 and figure 1-2.) Since 1990, Federal R&D expenditures measured in constant dollars have declined, while those of industry, universities and colleges, and other sources have continued to increase. In 1998, industry accounted for 65.1 percent of

[50] Because U.S. Government accounting conventions changed during the early 1950s, precise comparisons of current R&D expenditure levels with those in the 1940s and earlier are difficult to make. (See footnote 43.)

Figure 1-2.
National R&D performance, by type of performer: 1953–1998



FFRDC = Federally Funded Research and Development Centers

See appendix tables 2-3 and 2-4.

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national R&D investments, the Federal Government 30.2 percent, the academic sector 2.3 percent, and other sources 2.4 percent. (See chapter 2.)

Today, both *Science in the National Interest* and *Unlocking Our Future* emphasized that Federal Government R&D expenditures will remain constrained during the foreseeable future and that industry will continue to be the dominant funder of R&D. Both also noted the importance of the complementary support roles of government and industry in maintaining the vitality of the total national science and engineering system.

Role of Nonprofit Organizations

A unique aspect of the U.S. system is the role that nonprofit organizations play in the support and conduct of research. One of the four committee reports appended to *Science—The Endless Frontier* included pre-World War II expenditure estimates for research support by nonprofit organizations (Bush 1945a, 86). In 1940, these amounted to approximately $4.5 million, compared with an estimated $31.5 million expended by universities for their research. *Science and Public Policy* acknowledged that, although nonprofit organizations had played important roles in supporting basic research, their expenditures were unlikely to increase significantly (Steelman 1947, vol. I, 27). This assertion provided one basis for the argument that a stronger Federal role in basic research support was essential.

Today, nonprofit organizations accounted for an estimated $3.4 billion in R&D expenditures in 1998, compared with the approximately $5.0 billion expended for R&D by universities and colleges from their own sources. Research facilities operated by nonprofit organizations received an estimated $2.9 billion in Federal support for their research during that same year. These facilities occupy a unique, important niche in the national research system. After having been eclipsed as significant sources of research support, nonprofit organizations and their strategic roles are again being recognized—particularly in technology development and health-related research. For this reason, NSF is currently conducting a substantial study that aims to determine in more detail the current roles of nonprofit organizations in the U.S. science and engineering enterprise. (See chapter 2.)

Defense R&D

The importance of scientific research and engineering development to national security has been among the most enduring science policy themes. *Science—The Endless Frontier* recommended that a Division of Defense Research should be established within the proposed National Research Foundation and allocated approximately 30 percent of its budget during the first year, decreasing in relative terms to about 16 percent by the fifth year (Bush 1945a, 40). (See text table 1-5.) This division would have been authorized to support defense-related research in civilian institutions without recourse to, or approval by, any military authority.

By contrast, *Science and Public Policy* argued that Federal R&D allocations were distorted, with defense-related expenditures too large relative to nondefense components. In 1947, the combined R&D budgets of the War and Navy departments accounted for 80 percent of all Federal R&D expenditures. (See text table 1-4.) The report recognized that the absolute level of defense R&D was probably appropriate and that there was no short-term prospect for any significant reduction (Steelman 1947, vol. I, 21–3). Therefore, it recommended that, over the long term, greater emphasis should be placed on increasing other components of the Federal R&D budget so that by 1957, defense R&D would account for 22 percent of the total.

Today, both defense and nondefense R&D expenditures have grown to levels vastly higher than envisaged 50 years

Text table 1-5.
Proposed National Research Foundation budget
In millions of U.S. dollars

Activity (by division)	First year: 1945 current	First year: 1998 constant	First year: Percent	Fifth year: 1945 current	Fifth year: 1998 constant	Fifth year: Percent
Medical research	5.0	41.3	14.9	20.0	165.4	16.3
Natural sciences	10.0	82.7	29.9	50.0	413.4	40.8
National defense	10.0	82.7	29.9	20.0	165.4	16.3
Scientific personnel and education	7.0	57.9	20.9	29.0	239.8	23.7
Publications and collaboration	0.5	4.1	1.5	1.0	8.3	0.8
Administration	1.0	8.3	3.0	2.5	20.7	2.0
Total	33.5	277.0	100.0	122.5	1,012.9	100.0

NOTE: Details may not sum to totals because of rounding.

SOURCE: Vannevar Bush, *Science—The Endless Frontier: A Report to the President on a Program for Postwar Scientific Research* (1945a). Reprinted by NSF (Washington, DC: 1990).

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ago, each responding to changing needs and opportunities.[51] During the Strategic Defense Initiative era of the 1980s, defense R&D expenditures accounted for almost 80 percent of the total Federal R&D budget. But that situation has changed. The fraction of defense R&D in the Federal R&D budget, which by 1989 had declined to approximately 61 percent of all Federal R&D expenditures, continued to decline to 48.5 percent in 1997. The Clinton Administration's budget for fiscal year 2000 proposed expending $35.1 billion for defense R&D, or 44.5 percent of the $78.2 billion proposed for total Federal R&D expenditures.[52] (See chapter 2.)

Health-Related Research

Among the unique characteristics of the U.S. system is the high level of support that the Federal R&D budget allocates to health-related research. But this was not the case in the late 1940s. One of the four committee reports appended to *Science—The Endless Frontier* dealt exclusively with health research and laid particular emphasis on the need to increase support for basic research underlying medical advances (Bush 1945a, 46–69). The body of the report recommended that a Division of Medical Research should be established within its proposed National Research Foundation and allocated 15 to 16 percent of its total budget (Bush 1945a, 40). (See text table 1-5.) *Science and Public Policy* argued that Federal investments in health-related research were inadequate. It recommended that these investments should be tripled during the next 10 years so that they would then constitute 14 percent of the Federal R&D budget (Steelman 1947, vol. I, 28).

Today, health-related R&D accounts for the largest fraction of the Federal nondefense R&D budget. In FY 1999, the R&D budget of the Department of Health and Human Services was $15.8 billion—almost 20 percent of total Federal R&D budget, and slightly less than 38 percent of Federal nondefense R&D (NSF 1998). *Science in the National Interest* assigned a high priority to health as a core element of the national interest, emphasizing that a wide range of scientific disciplines, including the physical, social, and behavioral sciences, in addition to the biomedical sciences, make essential contributions (Clinton and Gore 1994, 3). (See chapter 2.)

Centrality of the University System

Support for University Research

Science—The Endless Frontier's recommendation that the Federal Government should assume major responsibility for supporting research in universities was, of course, its most novel feature; the proposed National Research Foundation was to be the principal means for discharging this new function. Bush proposed that the budget for the new agency should be $33.5 million for the first year, rising to a steady state level of $122.5 by the fifth year (Bush 1945a, 40). (See text table 1-5.) These amounts were to be allocated to research in all fields of science, including defense and medical research (but excluding the social sciences) and to a scholarship and fellowship program.

Science and Public Policy also emphasized the Federal role in supporting university research. Following Bush, it recommended the creation of a National Science Foundation, but excluded the defense research support function proposed by Bush, while explicitly including support for the social sciences.[53] The report recommended that the initial budget of the proposed National Science Foundation should be $50 mil-

[51]Compare this with Office of Science and Technology Policy (1995). This policy document, based on a White House Forum held at NAS March 29–30, 1995, considered environmental and economic security issues as well as military security.

[52]*Budget of the United States Government for Fiscal Year 2000*, Executive Summary, p. 107, table 7-1.

[53]See Steelman (1947, vol. I, 31–2). Section 3(a)(2) of the National Science Foundation Act of 1950 "directed and authorized" the Foundation to support research in the "mathematical, physical, medical, biological, engineering, and other sciences." The 1968 Daddario Amendments to the National Science Foundation Act added the social sciences to this enumeration.

lion, rising to $250 million after 10 years when it should account for 20 percent of the total Federal R&D budget.

Today, because recommendations from these key policy documents of the early transition period were taken seriously, universities have come to occupy the vital center of the U.S. national research system, a situation which is unique to the United States. Both *Science in the National Interest* and *Unlocking Our Future* explicitly recognize their central roles, and there is a widespread consensus about the need to provide adequate support for university research. Issues now have to do with the balance of support for academic research among fields and disciplines. The significance of interdisciplinary research to address national objectives is increasingly stressed, as is the importance of research in the social and behavioral sciences.[54] (See chapter 6.)

Support for University Research Facilities

One of the four committee reports appended to *Science—The Endless Frontier* included pre-World War II data on capital expenditures for university research (Bush 1945a, 87). *Science and Public Policy* emphasized that "additional libraries, laboratory space and equipment are urgently needed, not only in terms of the [report's] contemplated program of basic research, but to train scientists for research and development programs in the future" (Steelman 1947, vol. I, 37). It urged that provision be made for Federal aid to educational institutions for the construction of facilities and the purchase of expensive equipment.

Today, there is still concern about the adequacy of academic research facilities. As evidence of the bipartisan character of its interest, Congress requires NSF to issue a periodic report on the state of academic facilities for basic research. (See chapter 6.)

Human Resources for Science and Engineering

Supply and Demand for Scientists and Engineers

The deficit of trained scientists and engineers resulting from World War II was one of the primary concerns of both *Science—The Endless Frontier* and *Science and Public Policy.* The Bush report included a section on this problem, entitled "Renewing our Scientific Talent" (Bush 1945a, 23–7). A chapter on human resources in volume I of the Steelman report estimated that there was at that time (1947) a deficit of 90,000 scientists at the bachelor's level and 5,000 at the doctoral level (Steelman 1947, vol. I, 15–23). It went on to estimate, on the basis of demographic data, that it would require 10 years before the numbers of scientists at these two levels would reach the numbers that might have reasonably been expected if World War II had not intervened. By the mid-1950s these deficits had largely been alleviated, thanks in part to educational support provided to returning veterans by the GI bill of rights and, beginning in the early 1950s, to Federal Government predoctoral and postdoctoral fellowship programs.[55]

Today, demand for scientists and engineers continues to be high, although there is considerable variation by field and sector. Unemployment rates for this population are consistently lower than for persons trained at similar levels in other fields, while employment in the science and engineering sector is projected to increase at more than three times the rate for all occupations. (See chapter 3.)

Research by Academic Faculty

Science and Public Policy paid particular attention to human resources in the academic sector. It emphasized the importance of the links between research and teaching responsibilities of faculty in U.S. colleges and universities that had both research and teaching responsibilities, but the conditions then prevailing in those institutions frequently did not permit faculty to exercise those responsibilities effectively (Steelman 1947, vol. I, 19–20). Teaching loads had increased significantly since the end of World War II as a result of the doubling of the number of science and engineering students—many of them returning veterans—over prewar levels. One result was a diminished capacity for research in the academic sector. The report estimated that it would take 15,000 additional qualified science and engineering instructors to restore the prewar student–teacher ratio in U.S. colleges and universities.

Today, tenure track positions in colleges and universities are highly competitive. This has led to considerable demoralization among younger scientists, owing to diminishing opportunities to obtain positions either in academia or industry where they can continue to pursue the type of basic research they performed as graduate students. The amount of research experience required to qualify for a tenure track position has continued to increase. As a result, a large percentage of recent Ph.D.s aspiring to academic careers hold postdoctoral positions, which were relatively rare in the 1940s. There is widespread concern that academia is "overproducing" Ph.D.s—particularly for academic positions. After years of relative neglect, establishing effective links between research and education has reemerged as a salient policy issue. (See chapter 3.)

Science and Engineering Education at the Undergraduate and Graduate Levels

Science and Public Policy pointed out that the above-noted shortages of qualified science and engineering instructors in U.S. colleges and universities, coupled with increasing enrollments, was also undermining the quality of undergraduate science and engineering education (Steelman 1947, vol. I, 16–20). Neither *Science—The Endless Frontier* nor *Science and Public Policy* considered details of graduate study curricula explicitly. However, the latter included a report commissioned from AAAS on "The Present Effectiveness of Our Schools in the Training of Scientists," which discussed the

[54]NSF created a Directorate for Social, Behavioral, and Economic Sciences in January 1992.

[55]The first NSF fellowships, consisting of 535 predoctoral and 38 postdoctoral awards, were made in the spring of 1952 at a total cost of $1.53 million, or approximately $8.7 million in constant 1998 dollars (NSF 1952, 55, 75).

recruitment, retention, and support of graduate students in science and engineering (Steelman 1947, vol. IV, 131–40).

Today, after several years of rapid expansion, enrollments in higher education in the United States have leveled off. Issues associated with graduate education in science and engineering remain salient, particularly the retention, training, and support of graduate students.[56] (See chapter 4.)

Foreign Students in U.S. Universities

Science and Public Policy recommended that foreign students should be encouraged to attend U.S. colleges and universities, noting that it might be some time before most of the first-rate European institutions would recover completely from the devastation of World War II (Steelman 1947, vol. I, 39–40). It conceded that the crowded conditions then prevailing at many of these institutions might make it difficult for them to accept too many foreign students. On the other hand, it suggested such a program, which it noted might be supported through the recently established Fulbright Program for International Educational Exchange, would be an important contribution to international goodwill.[57]

Today, foreign-born students are a significant presence in U.S. universities, particularly in science and engineering programs at the graduate level. Asian students predominate. There is some concern about the fact that the number of foreign students in some disciplines is larger (in some cases far larger) than the number of U.S. students. (See chapter 4.)

Elementary and Secondary Education

Both *Science—The Endless Frontier* and *Science and Public Policy* recognized the importance of elementary and secondary education. The former report emphasized that "improvement in the teaching of science is imperative, for students of latent scientific ability are particularly vulnerable to high school teaching, which fails to awaken interest or to provide adequate instruction. To enlarge the group of specially qualified men and women it is necessary to increase the number who go to college" (Bush 1945a, 26). One of its four appended committee reports included a section entitled "The Education Pyramid: Studies Concerning Able Students Lost to Higher Education" (Bush 1945a, 166–76). Although data specific to mathematics and science education were not included, the section urged that improvements in instruction in all subjects were essential if a greater proportion of qualified students were to go on to higher education.

Volume IV of *Science and Public Policy*, which was devoted entirely to human resources for science and engineering, included an extensive survey and analysis of the condition of mathematics, science, and engineering education from the primary through the undergraduate–graduate levels (Steelman 1947, vol. IV, 47–162). This analysis pointed to a number of deficiencies in mathematics and science instruction at the elementary and secondary levels and made specific recommendations for remedial action.

Today, student achievement, curriculum and instruction, and teacher preparation have become issues of national importance. Repeated studies during the past three decades indicate that U.S. students do not perform as well in mathematics or science as do their peers in many other nations. More recent studies point to a far less challenging curriculum and less demanding instructional practices as key factors in that performance. Minority students and women tend to perform less well and to take fewer demanding mathematics and science courses. (See chapter 5.)

Significance of Industrial R&D

R&D and Economic Growth

Both *Science—The Endless Frontier* and *Science and Public Policy* emphasized the importance of R&D to economic growth. The former dealt with the theme in terms of science, technology, and job creation noting that,

> one of our hopes is that after the war there will be full employment, and that the production of goods and services will serve to raise our standard of living. There must be a stream of new scientific knowledge to turn the wheels of private and public enterprise. There must be plenty of men and women trained in science and technology for upon them depend both the creation of new knowledge and its application to practical purposes (Bush 1945a, 6).

Science and Public Policy approached the economic growth theme in terms of U.S. leadership stressing that, "if we are to remain a bulwark of democracy in the world, we must continually strengthen and expand our domestic economy and our foreign trade. A principal means to this end is through the constant advancement of scientific knowledge and the consequent steady improvement of our technology" (Steelman 1947, vol. I, 3–4).

Today, the importance of science-related and high-technology industries in terms of both job creation and international standing is widely recognized. (See chapter 7.) *Science in the National Interest* emphasized prosperity as a core element of the national interest, stating that "Prosperity requires technological innovation. Basic scientific and engineering research is essential for training innovative scientists and engineers, for many technology improvements, and for achieving the revolutionary advances that create new industries" (Clinton and Gore 1994, 4).

Domestic Competition

Science and Public Policy gave several reasons for the impressive increase in industrial R&D expenditures during the two years since the end of World War II. In particular, it noted that "competition, in many instances, is forcing a rapid exploitation of scientific advances" (Steelman 1947, vol. I, 22).

Today, successful competition in the domestic market relies heavily on industrial R&D investments. *Unlocking Our Future* noted that:

[56]See, for example, NSB (1997).

[57]An Act To Amend the Surplus Property Act of 1944 To Designate the Department of State as the Disposal Agency for Surplus Property Outside the United States. Public Law 79-584, enacted August 1, 1946. Senator William J. Fulbright of Arkansas introduced provisions in this legislation to permit the use of U.S.-owned foreign currency for educational exchanges.

> Today's technology-driven company must bridge the research gap between basic science and product development if it wants to remain on the cutting edge of the industry. This research is typically necessary to develop basic research results into an emerging technology and then into a marketable product (U.S. House of Representatives Science Committee 1998, 24).

Increasing competition has led to a fundamental structural change in the character of industrial research. Formerly, a good deal of that research, including a reasonable amount of basic research, was conducted in centralized corporate laboratories. However, most of that research has been divested to individual business units on the grounds that research results can thereby be captured more immediately and effectively for commercial developments. The decline of corporate research laboratories as performers of basic research has increased the importance of university basic research to industry, indicating the need for effective partnerships between these two sectors. (See chapter 7.)

International Competition

Science and Public Policy emphasized that the economic and technological supremacy that the United States enjoyed in 1947 was a partial result of the wartime devastation that other industrialized countries had experienced. It went on to warn that,

> the future is certain to confront us with competition from other national economies of a sort we have not hitherto had to meet. Many of these will be state-directed in the interest of national policies. Many will be supported by new, highly efficient industrial plant and equipment—by the most modern technology. The destructiveness of the recent war makes it inevitable that much of Europe, in rebuilding its factories, will soon possess an industrial plant more modern than ours today (Steelman 1947, vol. I, 4).

Today, high-technology exports are a critical contributor to the U.S. balance of trade. The United States is dominant in the export of technology. However, in some vital areas of technology, the capabilities of Japan or one or more European countries are at least on a par with those of the United States, and in a few cases may actually exceed those of this country. High-technology competition from several emerging economies is also increasing. (See chapter 7.)

The Federal Role

Support for Science and Engineering Students

Both *Science—The Endless Frontier* and *Science and Public Policy* recommended that the Federal Government should establish undergraduate scholarship and graduate fellowship programs as a means to alleviate the wartime deficit of scientists and engineers (Bush 1945a, 26–7; Steelman 1947, vol. I, 7). Both emphasized that, in addition to helping relieve the deficits, an undergraduate scholarship program would make it possible for all qualified students to obtain a college education even if their families lacked the requisite financial resources. For that reason, both recommended that the scholarship program should encompass fields other than science and engineering. The recommended undergraduate scholarship programs were never implemented in the form recommended by the two reports. However, Title II of the Servicemen's Readjustment Act of 1944, commonly known as the GI bill of rights, provided support for returning veterans to attend college and led to the results that both reports had hoped would occur—namely, the democratization of U.S. higher education.[58]

Today, the democratization of higher education has improved, in the sense that more qualified students are able to obtain an education at the undergraduate level. Nonetheless, there are serious concerns about unevenness in demographic representation in science and engineering fields, particularly for women and for racial and ethnic minorities. (See chapter 4.) Additionally, there are continuing problems with and differences in the quality of K–12 education throughout the Nation, a factor influencing access to higher education. (See chapter 5.)

Federal Role Vis-à-Vis Industrial Research

Then as now, the appropriate role of the Federal Government *vis-à-vis* the industrial research sector was an issue of primary importance. *Science—The Endless Frontier* took the position that the Federal Government should not provide direct financial support for nondefense research in industry, nor interfere in any way with industry's prerogative to determine its own research priorities and directions. It asserted that "the simplest and most effective" way that government could assist industry would be to support basic research in universities and help ensure that there would be an adequate number of trained scientists and engineers. The report also recommended clarification of the tax code on the matter of the deductibility of R&D expenditures and a simplification of the patent system to reduce the cost of patent filing, in part because filing costs often discouraged businesses from investing in R&D (Bush 1945a, 21).

While agreeing that industry should determine its own research priorities, *Science and Public Policy* was more flexible on the matter of Federal support. In fact, it argued that Federal Government expenditures for nondefense development were too small relative to its defense expenditures. The report noted that, of the estimated $625 million expended by the Federal Government for R&D in contracts to industrial and university laboratories in 1947, $500 million was accounted for by the Departments of War and Navy.[59] (See text table 1-4.) In addition to increasing support for university research by a factor of four by 1957, it recommended doubling support for nondefense development so that it would constitute 44 percent of the Federal R&D budget by that same year (Steelman 1947, vol. I, 28).

Today, both *Science in the National Interest* and *Unlocking Our Future* emphasized intersectoral partnerships and alliances as key elements in a vital national research system. The importance and legitimacy of the Federal role in cata-

[58]Public Law 78-346, enacted June 22, 1944.

[59]The Departments of War and Navy were combined into the Department of Defense in 1947.

lyzing and facilitating partnerships and alliances is widely accepted. In addition, there are also a few relatively modest Federal programs to provide partial support for particularly risky research in industry. (See chapter 7.)

Coordination of Federal Research Policy and Programs

Volume II of *Science and Public Policy* was devoted entirely to "The Federal Research Program," while volume III dealt with "Administration for Research." The principal conclusions of these volumes were summarized in a chapter in the first, summary volume titled "Federal Organization for Science" (Steelman 1947, 61–7). This chapter recommended that "(1) An Interdepartmental Committee for Scientific Research should be created; (2) The Bureau of the Budget should set up a unit for reviewing Federal scientific research and development programs; and (3) The President should designate a member of the White House staff for scientific liaison."

Today, all of these recommendations have been implemented. The functions of the Interdepartmental Committee for Scientific Research and Development, which was created in December 1947 and became the Federal Coordinating Committee for Science and Technology in November 1957, were later expanded and subsumed by the FCCSET, which was established in 1976 by the same Act of Congress that created the OSTP.[60] In 1993, FCCSET was subsumed in turn into the NSTC, which is chaired by the President and includes the heads of all Federal agencies and bureaus with significant science and technology responsibilities, as well as other Federal Government officials—most prominently the President's Assistant for Science and Technology (commonly known as the President's Science Advisor) and the director of the Office of Management and Budget. These two officials have been working together closely for several years to develop a coherent Federal R&D budget aimed at addressing administration science and technology priorities. At the beginning of each annual budget cycle, they co-sign a letter to the heads of all relevant agencies that contains instructions relevant to the preparation of budget proposals in specific categories related to the priorities and strategic goals of the Administration. The Congress also remains concerned with the problem of ensuring that the Federal Government's science and technology programs effectively address significant national issues, as evidenced most recently in *Unlocking Our Future* (U.S. House of Representatives Science Committee 1998).

International Considerations

International Aspects of U.S. Science Policy

Science and Public Policy recommended that, as part of the Marshall Plan proposed by Secretary of State George C. Marshall at the June 5, 1947, Harvard University commencement, "every effort [should] be made to assist in the reconstruction of European laboratories" (Steelman 1947, vol. I, 7). It also recommended that scientific missions should be established in U.S. embassies in scientifically important countries and that foreign students should be encouraged to study in U.S. universities (Steelman 1947, vol. I, 38–40). *Science—The Endless Frontier* emphasized the importance of international exchange of scientific information to the U.S. research enterprise (Bush 1945a, 22). It recommended Federal Government support for (1) American scientists to attend international scientific meetings abroad, (2) visits to the United States by prominent foreign scientists, (3) international fellowships for U.S. scientists, and (4) translation services.

Today, the global character of science and technology is evident from R&D investments in other countries which, particularly among a majority of the G-7 countries (Canada, France, Germany, Italy, Japan, and the United Kingdom, in addition to the United States), include substantial industrial as well as government components. (See chapter 2.) The substantial research and educational resources and science and engineering talent existing in countries throughout the world has enhanced opportunities for mutually beneficial international cooperation involving university and industry researchers, including research experience for graduate students and postdoctoral researchers.[61]

Beginning in the early 1950s, *Science and Public Policy*'s recommendation that scientific missions should be established in important U.S. embassies abroad began to be implemented with the appointment of Science and Technology Counselors in many of these missions. However, the number of these positions has declined considerably during the 1990s, as has the importance accorded science and technology as elements of U.S. foreign policy.[62]

Research in the Soviet Union/Russia

Science and Public Policy pointed to the Soviet Union as the principal scientific competitor of the United States, noting that its 1947 R&D budget reportedly had increased to $1.2 billion as compared with outlays of $900 million in 1946 (Bush 1945a, 5–6). It also remarked that the country had embarked upon a five-year program of stepped-up training for scientists and engineers.

Today, the Soviet Union no longer exists as a political entity. R&D expenditures in Russia (which contained the major concentration of the Soviet Union's scientific resources) have declined sharply from an estimated 2.03 percent of GDP in 1989 to about 0.73 percent in 1995. Knowledgeable U.S. observers continue to regard Russia as a scientifically and technologically significant country, noting its substantial and important past contributions to research in many disciplines. Yet they also emphasize that the country must resolve formidable economic problems before it can once again make sub-

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[60]Public Law 94-282.

[61]Several NSF programs facilitate research experiences abroad at the graduate and postdoctoral and, to some extent, the undergraduate level as well. NSF's overseas offices in Tokyo and Paris issue frequent reports on research opportunities in Japan and Europe.

[62]Compare this with the Carnegie Commission on Science, Technology, and Government (1992); Watkins (1997, 650–1); U.S. House of Representatives Science Committee (1998, 22–4).

stantial contributions to the global science and technology enterprise. (See chapter 2.)

Significance of Developing Countries

The Steelman report pointed to India as a country where progress was being made in the construction of new scientific research laboratories and in the training of first-rate researchers (Steelman 1947, vol. I, 41). It predicted that similar developments could be anticipated in China and in Latin America.

Today, the developed countries (primarily the United States and Canada, Western Europe, and Japan) still account for by far the largest fraction of the world's R&D expenditures, with the United States, Japan, Germany, France, and the United Kingdom expending more than 2 percent of GDP for these purposes. By contrast, the R&D expenditures of China, India, and Brazil, for example, are estimated to be somewhat less than 1 percent of their GDPs. Despite their relatively modest R&D investments, all three countries have produced world-class scientists and engineers and have developed impressive, competitive capabilities in several important areas. Many scientists and engineers from the United States and other developed countries have enjoyed cooperative working relations with colleagues from these and other developing countries for several years. (See chapters 2, 4, 6, and 7.)

Public Attitudes and Understanding of Science and Technology

Although the analysis of mathematics and science education by AAAS included in *Science and Public Policy* dealt primarily with the production of professional scientists and engineers, a section entitled "Science and General Culture" also emphasized the importance of science education for nonspecialists. It suggested that "maintenance of the crucially necessary supply of research talent, and integration of the sciences into a sound ethical structure of society without which civilization cannot survive, are both dependent upon adequate representation of science in our educational system"(Steelman 1947, vol. IV, 113).

Today, both *Science in the National Interest* and *Unlocking Our Future* emphasized the importance of public attitudes and understanding both to the vitality of the science and engineering enterprise and to the Nation, particularly since understanding many significant national issues requires some familiarity with science and technology. It has also been recognized that the level of public understanding of adults is strongly correlated with the adequacy of the science and mathematics education they receive at the primary and secondary school levels.[63] Bipartisan support is evidenced by the consistently high level of NSF's annual education and human resources appropriations, $689 million in FY 1999. (See chapter 8.)

[63]The widespread consensus about the importance of science and mathematics education at the primary, secondary, and undergraduate levels is suggested by the fact that NSF's annual budget for education and human resource development currently exceeds $600 million.

Impacts of Information Technology

Had the term "information technology" been in use in the 1940s, it might well have referred to developments in communications technology—namely, radio and perhaps even television—that had been successfully demonstrated immediately before the outbreak of World War II but were not commercialized until a few years later. *Science—The Endless Frontier* did cite radio as one of several technologies whose widespread commercialization occurred after the end of World War I. It did so to suggest, by inference, that new and at that time (1945) unimagined technologies would almost certainly result from the applications of post-World War II research. However, neither the Bush nor the Steelman reports speculated about what those future technologies might be.

But on a personal level, Vannevar Bush foresaw the development of what is now called the digital library. In an article published in the Atlantic Monthly in July 1945 (the same month that *Science—The Endless Frontier* was delivered to President Truman), Bush invited his readers to …

> Consider a future device for individual use, which is a sort of mechanized private file and library. It needs a name, and to coin one at random, "memex" will do. A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory (Bush 1945b).

Today, information technology, based on a merging of computer and communications technologies, has become ubiquitous. Information technology has had an impact on virtually all sectors of our economy and society, including the conduct of research, as well as on our daily lives. The digital libraries that Bush foresaw more than a half-century ago are becoming a reality, even though based on very different technologies than he envisioned. Nor did he foresee the possibilities that digital libraries separated by great spatial distances could be linked electronically and accessed from other distant locations. (See chapter 9.)

Current Emerging Themes

As discussed in "A Program for the National Science Foundation," the NSB determined during its first year that one of its major responsibilities would be to ensure that the condition of the U.S. (and global) science and technology enterprise would be monitored. Since 1972, its *Indicators* reports have been the most visible manifestation of that determination. The NSB published a strategic plan in November 1998 that emphasized its commitment to *Science and Engineering Indicators* as an instrument for assessing the overall health of the enterprise and for providing a robust basis for decisionmaking in national science and engineering policy, as well as its determination to continually improve this instrument to serve these objectives (NSB 1998c). These reports have also provided the Board with opportunities to point to both emerging themes and to emphasize transmutations in the more traditional themes that began to be evident 50 years ago.